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EVN observations of 6.7 GHz methanol masers from Medicina survey

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Abstract. We report VLBI observations of methanol masers in the brightest $5_1 - 6_0$ A^+ transition at 6.7 GHz in NGC 281W, 18151−1208 and 19388+2357. Using the fringe rate method, absolute positions were obtained for all observed sources. A linear ordered structure with a velocity gradient was revealed in NGC 281W. Under the assumption that such a structure is an edge-on Keplerian disk around the central object with a mass of $30M_\odot$, located at a distance of 3.5 kpc from the Sun, we estimated that the methanol masers are situated at a distance of about 400 AU from the center of the disk. A second epoch of observations is reported for L1206, GL2789 and 20062+3550. The upper limits on the relative motions of maser spots are estimated to be 4.7 km s^{-1} and 28 km s^{-1} for L1206 and GL2789 respectively.

1. Introduction

The $5_1 - 6_0$ A^+ methanol transition at 6.7 GHz produces the brightest known methanol masers. Many recent interferometric studies of such masers reveal geometrically ordered structures formed by maser spots sometimes with velocity gradients (Norris et al. 1993, Phillips et al. 1998, Minier et al. 2000). Such linear structures can be explained in the model of a rotating Keplerian disk seen edge-on. The goal of this work is to map using EVN several methanol masers discovered in the Medicina survey (Slysh et al. 1999) and to search for geometrically ordered structures in these sources.

2. Results and Discussion

The EVN observations were carried out in 1998 and 2000. In total, images of 6 sources were produced with 3 of them being imaged in both epochs of observations. Analysis of these images yields relative positions and flux densities of individual maser spots which are shown in Table 1. During the post-processing, absolute positions for the reference features were determined using the fringe rate method. Two sources, L1206 and GL2789, were described in detail earlier by Voronkov & Slysh (2001) and Val'tts et al. (2002). Among the sources observed in both sessions, these two masers are the only sources which consist of multiple components and so may be used to study relative motions of maser spots. The upper limits on these motions are estimated to be 4.7 km s^{-1} and 28 km s^{-1} for L1206 (1 kpc) and GL2789 (6 kpc) respectively. For the sources 19388+2357 and 20062+3550 we detected only one spectral feature in the correlated spectrum. The lower limits on the brightness temperature are 5.9×10^{11} K and 1.3×10^{10} K for 19388+2357 and 20062+3550 respectively.

In addition to GL2789 and L1206, where the spatially ordered structures with a velocity gradient were revealed in the previous studies cited above, such a structure was found in the maser NGC 281W. The spectrum and the map of this source are shown in Fig. 1 and Fig. 2. The

Table 1. Relative positions and flux densities of individual maser spots. Typical positional accuracy is about 2 mas.

Source		V_{LSR} (km s^{-1})	$\Delta\alpha^a$ (mas)	$\Delta\delta$ (mas)	S (Jy)
		1998 year			
20062+3550		−2.62			2.2
GL2789	A	−43.37	−9	20.4	2.0
	B	−42.5	0	0	2.5
	C	−40.74	−2.5	−68.9	2.0
	D	−40.39	9.2	−78	2.2
L1206	A	−11.0	0	0	17.0
	B	−10.2	−93.7	35.9	1.0
			−85.7	28.0	1.0
		2000 year			
NGC 281W	A	−29.35	0	0	6.3
	B	−29.0	4.7	0.2	7.8
18151−1208	A	+27.65	0	0	2.8
	B	+28.1	−4.2	−3.4	5.9
			−2.8	−2.2	1.7
19388+2357		+38.21			18.0
20062+3550		−2.6			1.2
GL2789	A	−43.55	−7	20	2.5
	B	−42.5	0	0	1.2
	C	−40.82	−2.1	−69	1.7
	D	−40.48	10	−78	3.0
L1206[b]	A	−11.0	0	0	1.7
			−0.2	−6.0	2.1
	B	−10.2	−84.1	25.6	0.3

[a] – Taking into consideration the $\cos\delta$ factor.
[b] – The maps of the reference feature are considerably different for two epochs, so the error of relative positions may be high.

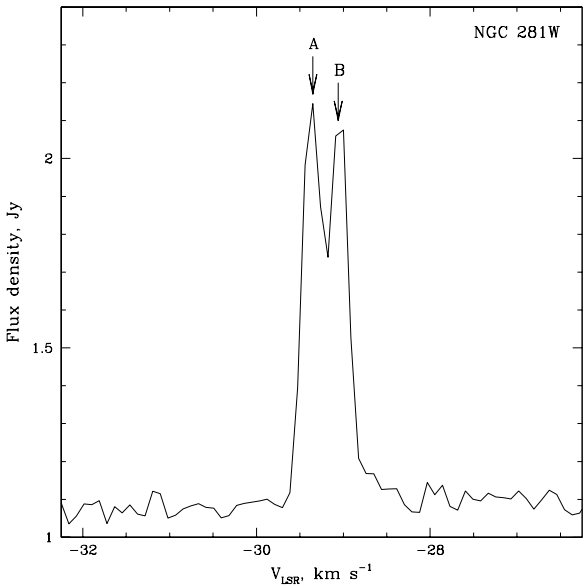

Fig. 1. The correlated spectrum of the methanol maser in NGC 281W on the short baseline Effelsberg – Jodrell Bank.

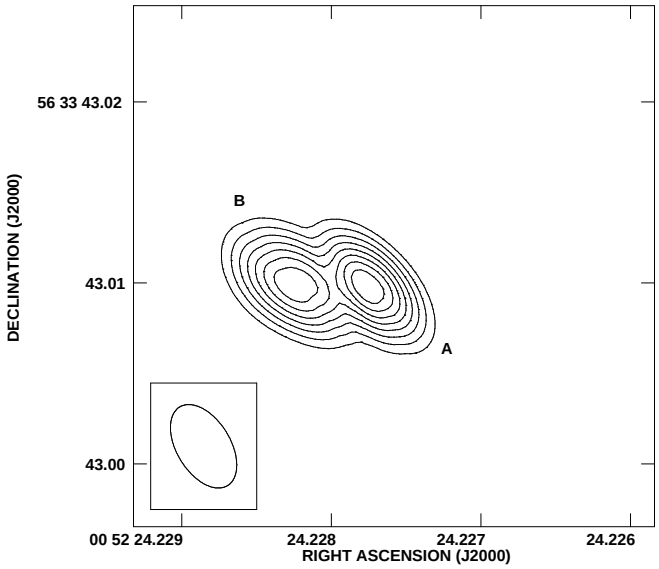

Fig. 2. The map of the methanol maser in NGC 281W. Contours are $0.6\times(2, 3, 4, 5, 6, 7, 8, 9)$ Jy beam^{-1}.

lower limit on the brightness temperature is 1.9×10^{10} K being almost the same for both spectral features. The map of each spectral channel is a point-like source. The position of this point source shifts from the spot A to the spot B in Fig. 2 while moving across the spectrum from the feature A to the feature B in Fig. 1. Such a gradient can be explained in a model where masers are formed in a Keplerian disk seen edge-on (Minier 2000). In this case the observed gradient $\frac{d\,V}{d\,x}$ of the radial velocity is

$$\frac{d\,V}{d\,x} = 30 \text{ km s}^{-1} \text{ AU}^{-1} \sqrt{\frac{M/M_\odot}{R^3_{\rm AU}}}, \quad (1)$$

where M is the mass of the central object (protostar), $R_{\rm AU}$ is the distance between the maser and the protostar (in AU). Assuming that the mass of the central object is about $30M_\odot$ and the distance from the Sun is about 3.5 kpc we estimate $R_{\rm AU}$ to be about 400 AU.

The spectrum of the source 18151−1208 consists of two features A and B (see Table 1). The maser spot corresponding to the most intense feature B was resolved into two spots at almost the same velocity. The maps of individual spectral channels do not show behavior similar to NGC 281W. This source shows fringes on the longest baseline Effelsberg−Hartebeesthoek (about 8000 km) which is probably unusual for the 6.7 GHz methanol masers. The lower limit on the brightness temperature is 1.4×10^{10} K for this source.

3. Conclusions

A geometrically ordered structure with a velocity gradient was revealed in the 6.7 GHz methanol maser in the star-forming region NGC 281W. If interpreted as an edge-on Keplerian disk around a protostar of mass about $30M_\odot$ located at a distance of 3.5 kpc from the Sun, such a structure implies a model where methanol masers are situated at a distance of 400 AU from the central object. This result is similar to that obtained for L1206 and GL2789. The brightness temperature for the most compact maser 19388+2357 exceeds 5.9×10^{11} K. The source 18151−1208 shows fringes on the Effelsberg−Hartebeesthoek (about 8000 km) baseline. The upper limits on the relative motions of maser spots are estimated to be 4.7 km s^{-1} and 28 km s^{-1} for L1206 and GL2789 respectively.

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